STATE OF THE STREAMS:

1995-1997 MARYLAND BIOLOGICAL

STREAM SURVEY RESULTS

Prepared for

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July 1999

FOREWORD

This report, *State of the Streams: 1995-1997 Maryland Biological Stream Survey Results,* supports the Maryland Department of Natural Resources' Maryland Biological Stream Survey (MBSS) under the direction of Dr. Ronald Klauda and Mr. Paul Kazyak of the Monitoring and Non-Tidal Assessment Division. This report was prepared under Maryland's Power Plant Research Program(Contract No. PR-96-055-001 to Versar, Inc.). Development of the statewide estimates of stream condition in this report was supported by the U.S. Environmental Protection Agency, Office of Research and Development, Regional Environmental Monitoring and Assessment Program (R-EMAP), through funds provided to Maryland DNR (Contract number Ca-98-11, 07-4-30528-3734, University of Maryland subcontract to Versar, Inc.). A major goal of the MBSS is to assess the impacts of acidic deposition on Maryland's headwater streams and their biological resources. The MBSS is also designed to characterize and assess biological, physical habitat, and water quality conditions of streams throughout the entire state, based on a three-year implementation schedule (1995-1997). This report presents statewide results from the 1995-1997 MBSS sampling years. This report includes a characterization of stream conditions, assessments based on ecological indicators, and analyses of the associations between human impacts and stream ecological conditions.

ACKNOWLEDGMENTS

The 1995-1997 MBSS has been a cooperative effort among several agencies and consultants. We at Versar wish to thank Ronald Klauda and Paul Kazyak from the Maryland Department of Natural Resources (DNR) for directing the program and supporting Versar in preparing this report. We are grateful to the staff of Post, Buckley, Schuh, and Jernigan, Inc. (formerly of Coastal Environmental Services) who selected sampling segments and provided statistical support. Maryland DNR, the University of Maryland's Appalachian Laboratory (AL), and the University of Maryland's Wye Research and Education Center (WREC) each provided field crews and did a great job collecting the data. Maryland DNR digitized watersheds and calculated land use data, provided quality assurance, conducted crew training, and performed field sampling. Jessica Schulman Farrar and Theresa Krebs of Versar contributed to writing this report. Mark Southerland and Paul Kazyak served as its editors. Valuable revisions were contributed by the following individuals who served as peer reviewers for this document: James Karr, David Allan, Thomas Schueler, Ed Pendleton, John Stoddard, Steve Paulsen, Robert Hughes, Wayne Davis, Ken Brown, and Ronald Klauda. We thank Marty Hurd and Ann Williams of Maryland DNR for GIS support in producing the land use data. Dr. Sam Stribling and his staff at Tetra Tech, Inc. developed the benthic Index of Biotic Integrity. Dr. Ray Morgan of AL and Mr. Lenwood Hall of the WREC supervised additional field crews and developed the Physical Habitat Index, and Dr. Keith Eshleman of AL assisted with analyses of data on acidified streams. Drs. Wayne Starnes and Bob Reynolds of the Smithsonian Institution (reptiles and amphibians), Dr. Rich Raesly of Frostburg State University (fish), Rita Villella of USGS Leetown Science Center (mussels), and Michael Naylor of Maryland DNR (aquatic vegetation) provided taxonomic verifications of voucher specimens. Ann Lenert, of Maryland DNR, prepared the report for printing and World Wide Web presentation. Versar designed the sampling program, obtained landowners' permissions, managed the data, and prepared this report. The success of the project resulted from the strong efforts of all these groups. We particularly thank the key individuals listed below for their contributions:

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Mike Gaughan
Don Strebel
Allison Brindley
Jessica Schulman Farrar
Theresa Krebs
Craig Bruce
Fred Kelley
Emily Rzemien
Kathy Bowles
Thuzar Myint
Gail Lucas
Sherian George
Sharon Huneycutt
Erin Klingebiel
Jim Hakala

AL
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Katie Meagher
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Rachel Burke
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David Neely
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Melanie Pacella
Walter Holtsmaster
Shelaine Curd
Mick Burkett
Jennifer Yantorno
Kristin Larson
Amy Gottesfeld
Brent Murry
Nancy Castro
Molly Kline
Sandy Davis
Todd Grote
Donna Gates

DNR
Ron Klauda
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Sue Kelley
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Sandy Ives
Doug Randle
Bill Rodney
Niles Primrose
Walt Butler
Ellen Friedman
Beverly Rayman
Ann Williams
Joyce Evans
William Evans
Robert Murphy

Wye Research and Education Center
Lenwood Hall
Mark Scott
Bill Killen
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Montgomery County
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Karl Routzahn

EXECUTIVE SUMMARY

This report summarizes results from the 1995-1997 sampling of the Maryland Biological Stream Survey (MBSS or the Survey) and provides the first statewide results on the assessment of the condition of Maryland's non-tidal streams. Supported and led by the Maryland Department of Natural Resources (DNR), the MBSS is a comprehensive program to assess the status of biological resources in Maryland's non-tidal streams; quantify the extent to which acidic deposition has affected or may be affecting critical biological resources in the state; examine which other water chemistry, physical habitat, and land use factors are important in explaining the current status of biological resources in streams; establish a benchmark for long-term monitoring of trends in these resources; and target future local-scale assessments and mitigation measures needed to restore degraded biological resources. To meet these and other objectives, the Survey has established a list of questions of interest to environmental decision makers to guide its design, implementation, and analysis. These questions fall into three categories: (1) characterizing biological resources and ecological conditions (such as the number of fish in a watershed or the number of stream miles with pH < 5), (2) assessing the condition of these resources (as deviation from minimally impacted expectations), and (3) identifying likely sources of degradation (by delineating relationships between biological conditions and anthropogenic stresses).

To answer these questions, a number of steps were undertaken to implement the Survey, including (1) devising a sampling design to monitor first- through third-order nontidal streams throughout the state and allow areawide estimates of the extent of the biological resources, (2) field testing sampling protocols and logistical arrangements to assure data quality and precision, (3) conducting an extensive, multi-year field sampling program, (4) developing indicators of biological condition (or integrity) so that degradation can be evaluated as a deviation from reference (or minimally impaired) expectations, and (5) using a variety of analytical methods to evaluate the contributions of different anthropogenic stresses, including land use. Completion of the 1993 MBSS Pilot Study and the 1994 MBSS Demonstration Project successfully addressed the design and sampling issues and provided preliminary results. In 1995, the first year of the three-year implementation of the Survey, research efforts focused on the development of biological indicators and better fish population estimation techniques. In 1996, the second year of implementation, these advances were applied to new data and enhanced analyses were conducted, including incorporation of more precise land use data. The final three-year report builds upon the previous years of the Survey. In addition to utilizing a refined fish Index of Biotic Integrity (IBI), this report presents the results of a newly developed benthic IBI and a Physical Habitat Index (PHI). These three indices are the basis for estimating the number of stream miles in varying degrees of degradation (good to very poor condition) and mapping the locations of sites by their condition.

Three characteristics of the Survey differentiate it from previous stream monitoring efforts in Maryland. First, sampling in the Survey is probability-based, allowing accurate and robust population estimates of variables such as abundances of particular species of fish and the number of stream miles with degraded habitat. The probability-based sampling design also permits estimation of sampling variance, so that estimates of status can be made with quantifiable confidence. Second, MBSS monitoring and assessments focus on biological responses to stress. Metrics for characterizing pollutant stress and habitat condition are measured simultaneously to provide a context for interpreting biological response. Third, the scale of the Survey is basinwide and statewide, rather than local. However, MBSS data can be used to assess stream condition at a county level and even for some smaller watersheds.

The Survey uses a special probability-based survey design called lattice sampling to ensure that non-tidal streams within all of the state's river basins can be sampled over a three-year period. The lattice design effectively stratifies by year and basin and restricts the sampling each year to about one-third of the state's 17 major drainage basins. This restriction is used to optimize the efficiency of the field effort by minimizing the travel time between sampling locations. Approximately 300 stream segments of fixed length (75 m) are sampled each year, with biological, chemical, and physical parameters measured at each segment using standardized methods. Biological measurements include the abundance, size, and individual health of fish; taxa composition of benthic macroinvertebrates; and presence of amphibians and reptiles, mussels, and aquatic vegetation. Chemical measurements include pH, acid-neutralizing capacity (ANC), sulfate, nitrate, conductivity, dissolved oxygen, and dissolved organic carbon (DOC). Physical habitat parameters include commonly used observational

measurements such as instream habitat structure, embeddedness, pool and riffle quality, bank stability, shading, and riparian vegetation, and quantitative measurements such as stream gradient, maximum depth, wetted width, and discharge. Other qualitative parameters measured at each site include aesthetic value, remoteness, and land use immediately visible from the segment. Additional land use information for the entire catchment upstream of each sample site was incorporated into the Survey from statewide geographic information system (GIS) coverages.

This 1995-1997 report presents the final results of the three-year cycle of sampling that completes the first round of the Survey. It documents the sampling of 955 segments in 17 of the state's major drainage basins and provides for statewide estimates of stream quality. The report first describes the environmental setting of Maryland, placing the results in the context of their geologic, climatic, and human history. It then characterizes stream conditions by estimating average conditions in each basin for most of the measured variables and by calculating the percentage of stream miles where one or more thresholds for selected variables were exceeded. It also assesses the quality of the streams by estimating the number of stream miles in each basin that meet the Index of Biotic Integrity (IBI) thresholds for good to fair fish and benthic macroinvertebrate communities based on the reference condition for that region. Relationships between specific characteristics of these streams, including the fish and benthic IBIs, and potential anthropogenic stresses are investigated. These major stressors include physical habitat degradation, acidification, nutrients, and land use impacts. A brief discussion is included of how MBSS results vary among sample years and implications for interpreting the results. A separate chapter uses the 1995-1997 MBSS results to discuss the condition of Maryland's aquatic biodiversity.

The geologic history, climate, physiography, geology, soils, and human influences on the landscape provide a useful context for assessing Maryland streams. As a result of glacial and post-glacial landform erosion, there are two major drainages in Maryland today: the Chesapeake Bay which empties into the Atlantic Ocean and the Youghiogheny River, which ultimately drains to the Mississippi River. All but one of the major river basins in Maryland drain into the Chesapeake Bay. Because these basins form natural ecological and aquatic management boundaries, they are the primary reporting units used for the Survey. Since the time of the last glaciation, a number of climatic events have occurred that have likely influenced the distribution of aquatic biota. It is important that MBSS and other data be interpreted in the context of such past abiotic conditions, even if the conditions only persist for weeks or days. Variations in precipitation, temperature, physiography, geology, and soils are also important when interpreting the results of the 1995-1997 MBSS. Human influences upon water quality extend to every part of the state. Practices such as forest management, agriculture, urbanization, and mining have had significant impacts upon both air and water quality in Maryland. The history of human influences on Maryland streams sets obvious limits on the number of high quality streams that can be preserved and the level of integrity to which they can be restored. Therefore, it is critical that natural resource managers develop an appropriate vision of desired conditions for Maryland streams and view the results of the Survey in that context.

During the 1995-1997 MBSS, 83 fish species were collected at the stream segments sampled using the MBSS stratified random sampling design. Occurrences not often reported included the endemic checkered sculpin (found in the Middle Potomac and Upper Potomac basins) and the non-native cutthroat trout (found in the North Branch Potomac and Patapsco basins). The density (number of individuals per stream mile) and abundance (number per basin) of individual game and non-game fish species were calculated from double-pass electrofishing data and corrected for capture efficiency. Statewide, the most abundant stream fishes were blacknose dace and mottled sculpin. Fish species richness per segment increased two-fold from the most western basin to the central basins and by four-fold in the eastern basins. Fish biomass followed a similar pattern. Gamefish abundance and distribution varied geographically and by stream order, with largemouth bass and brook trout by far the most abundant gamefish captured. Evidence indicates that the brook trout and American eel (an economically important species) have experienced precipitous declines as a result of human activities. Among all fish, external pathological abnormalities were observed infrequently. Statewide, 346 benthic macroinvertebrate genera within 112 families were collected. In general, basins on the Coastal Plain contained fewer benthic taxa than elsewhere in the state. Amphibians were present in approximately 50% of stream miles and salamander species richness was significantly greater in first- and second-order streams than in third-order streams. Eight species of freshwater bivalves were found throughout the state during 1995-1997 sampling. The Asiatic clam, a species introduced to Maryland in the 1930s, was found in 13 of the basins sampled. Twenty-four distinct species of aquatic vegetation were found. Aquatic plant species richness was highest in low-gradient, less shaded streams in the Coastal Plain.

Fish IBI scores for stream sites sampled in the 1995-1997 MBSS spanned a wide range of biological conditions, from good to very poor. Statewide, 45% of stream miles fell into the range of good to fair. An estimated 29% showed degradation (poor to very poor condition). The remaining 26% were not rated with the fish IBI because of small stream size. In the North Branch Potomac basin, 40% of the stream miles exhibited some level of degradation, while six basins (Gunpowder, Bush, Elk, Choptank, Nanticoke/Wicomico, and Pocomoke) had no sites with IBIs rated as very poor and less than 25% rated as poor. First-order streams had a smaller percentage of stream miles rated as good or fair than did larger streams.

Benthic IBI scores for the stream sites sampled in the 1995-1997 MBSS also spanned a wide range of biological conditions, from good to very poor. Statewide, 49% of stream miles fell into the range of good to fair, while 51% showed signs of degradation (poor to very poor conditions). The West Chesapeake basin contained 70% of stream miles rated very poor, while the Susquehanna basin had no sites rated very poor. As with the fish IBI, first-order streams had a smaller percentage of stream miles rated as good or fair than did larger streams. According to the Hilsenhoff Biotic Index (a benthic macroinvertebrate indicator of organic pollution), 78% of stream miles statewide were in good or fair condition using this indicator, while only 19% were in poor or very poor condition. The remaining 3% of stream miles were not rated using the Hilsenhoff Biotic Index because of small samples. All three of these biological indicators showed significant positive relationships to each other, although there was a large amount of variation at the statewide level.

The analysis of 1995-1997 MBSS data looked closely at physical habitat degradation of Maryland streams. Statewide, 28% of stream miles had no effective riparian buffer vegetation. An estimated 40% of stream miles had at least a 50 m vegetated riparian zone. An estimated 58% of all stream miles had forest cover and 14% had other types of vegetation in the riparian zone. Statewide, an estimated 4% of stream miles had beaver ponds, with the highest occurrence in the Lower Potomac basin (16%). Channelization occurred at an estimated 17% of stream miles in the state, with the highest occurrence in the Pocomoke basin (82%). Several instream condition parameters were also sampled during the 1995-1997 MBSS.

The Physical Habitat Index (PHI) is a reference-based indicator that combines many of the habitat metrics. PHI scores for stream sites sampled in the 1995-1997 MBSS spanned a wide range of biological conditions, from good to very poor. Statewide, 49% of stream miles were rated either good or fair and 51% were rated poor or very poor. The Elk basin received the best PHI rating, with 50% of stream miles in good condition and no stream miles in very poor condition. The West Chesapeake basin contained the largest percentage of stream miles in very poor condition (78%). A significant positive relationship was found between PHI and both the fish and benthic IBIs, indicating that physical habitat quality plays an important role in the health of fish and benthic macroinvertebrate communities. Although no indicator has been developed for amphibian and reptile species, their numbers did increase with PHI scores and with the width of the riparian buffer. Several individual habitat metrics were also correlated with IBI scores. Fish IBI scores were strongly related to instream habitat structure and maximum depth. Benthic IBI scores were most strongly correlated with riffle quality. Both indicators were correlated with aesthetic quality, riparian buffer width, and channel alteration.

MBSS sampling in 1995-1997 provided new information on the extent to which acidic deposition affects stream chemistry and biological resources in Maryland streams. Statewide, 2.6% of streams sampled in the spring and 1.8% of streams sampled in the summer had a pH less than 5. First-order streams had a higher percentage of stream miles with low pH than larger streams. Statewide, approximately 28% of the stream miles were acidic (ANC < 0 μeq/l) or acid-sensitive (ANC 0-200 μeq/l), with more than 60% of stream miles acid-sensitive in five basins (Lower Potomac, Pocomoke, North Branch Potomac, Youghiogheny, and Choptank). The preponderance of acidic and acid-sensitive stream miles in the basins of Western Maryland and the Coastal Plain is consistent with the findings of the 1987 Maryland Synoptic Stream Chemistry Survey (MSSCS). In general, ANC values for the 1995-1997 MBSS are slightly higher than those in the 1987 MSSCS, indicating an improvement in acid-base chemistry in streams over time.

For the 1995-1997 MBSS, analyses were conducted to estimate the extent of impacts by acidic deposition, acid mine drainage, organic acidity sources, and agriculture. Acidic deposition was by far the most common source of stream acidification, dominating 19% of stream miles; acid mine drainage (AMD) was the dominant source in about 1.4% of stream miles. An additional 1% of stream miles were likely affected by both acidic deposition and AMD. Only 0.8% were dominated by organic sources, while another 1.7% were likely affected by both organic acids and atmospheric deposition. Agriculture accounted for the acidification of 4.2% of all stream miles. The effects of AMD were greatest in the North Branch Potomac basin where approximately 25% of stream miles were affected. Substantial biological effects of acidification were also evident. Statewide, fish and benthic IBI scores showed a marked decline with low ANC, a pattern paralleled by other biological characteristics including fish species richness, abundance, and biomass. Only six fish species were found at sites with pH < 5. The density of individual fish species decreased dramatically at ANC < 200 μeq/l and species composition appeared to shift in favor of acid-tolerant species.

Elevated nitrogen concentrations are one indicator of nutrient enrichment in aquatic systems. Excessive nitrogen loading may lead to the eutrophication of the receiving water body, particularly in downstream estuaries. Eutrophication often decreases the level of dissolved oxygen available to aquatic organisms. Prolonged exposure to low dissolved oxygen values can suffocate adult fish or lead to reduced recruitment. Statewide, the majority of stream miles (59%) had nitrate-nitrogen (NO_3-N) concentrations greater than 1.0 mg/l. An estimated 41% of stream miles had NO_3-N concentrations between 0.1 mg/l and 1.0 mg/l, and only 0.4% had concentrations that were less than 0.1 mg/l. The mean statewide NO_3-N concentration was 2.45 mg/l. The following basins had average NO_3-N concentrations greater than the statewide average: the Middle Potomac, Patapsco, Gunpowder, Susquehanna, Elk, Chester, Choptank, and Nanticoke/Wicomico basins. For the most part, these were the same basins with sites with NO_3-N concentrations greater than 7.0 mg/l. Statewide, the majority of stream miles (94%) contained dissolved oxygen concentrations that were greater than 5.0 ppm, a level generally considered healthy for aquatic life (also the water quality standard for Maryland). An estimated 3% of stream miles had dissolved oxygen concentrations that fell between 3.0 ppm and 5.0 ppm, while 3% had concentrations less than 3.0 ppm.

The CORE/Trend program, begun in 1974, is part of Maryland's long-term ambient monitoring of stream water quality. Surface water samples are collected monthly at 55 stations located throughout the state and analyzed for a variety of physiochemical parameters. Stations from the CORE/Trend program are located in 11 of the 17 basins in the State: the Youghiogheny, North Branch Potomac, Upper Potomac, Middle Potomac, Potomac Washington Metro, Patuxent, Patapsco, Gunpowder, Susquehanna, Chester, and Choptank. Overall, the statewide average NO_3-N concentration from the CORE/Trend data was 1.82 mg/l, while the average statewide NO_3-N concentration from the MBSS data was 2.45 mg/l. Average NO_3-N concentrations in the Youghiogheny and the North Branch Potomac basins were both consistently low, showing very little difference between monitoring programs. In the Upper Potomac and Patuxent basins, the average NO_3-N concentration was higher at the CORE/Trend stations than at the MBSS sites. In the remaining basins sampled by both programs, the NO_3-N concentration was higher at the MBSS sample sites than at the CORE/Trend stations. The greatest difference was in the Choptank basin where MBSS sites had an average NO_3-N concentration of 3.66 mg/l, while the CORE/Trend sites had an average concentration of 1.32 mg/l. Differences in values within individual basins were, in part, explained by differences in sample site locations.

Landscape analysis is a useful tool for examining potential cumulative effects on stream systems at a large geographic scale. For sites sampled in the 1995-1997 MBSS, associations between upstream land use (using the Multi-Resolution Land Characteristics data set) and biological indicators of stream condition were analyzed. The extent of urban land use was greatest among sites in the Patapsco (average 31% of catchment area upstream of individual MBSS sites in the basin) and Potomac Washington Metro (23%) basins, and far lower in the remaining basins. Agricultural land use was approximately 60% or greater at stream sites in the Susquehanna, Middle Potomac, Gunpowder, and Elk basins. Forest cover was most extensive for sites in the North Branch Potomac basin (83%).

The proportion of land uses in a watershed strongly affects stream water quality. Streams in urban areas with more impervious surface tended to have higher water temperatures than streams in either agricultural or forested watersheds. Streams in areas with more than 50% agricultural land use in the watershed tended to have three times the mean NO_3-N concentration than streams with less than 50% agriculture. Land use also significantly affected IBI scores. Nearly all sites with greater than 50% urban land use had IBI scores indicative of poor to very poor biological condition. Statewide, fish and benthic IBI scores tended to decrease with increasing urban land use. These relationships were the strongest in the Patapsco and Potomac Washington Metro basins where the percentage of urban land is the greatest. IBI scores also decreased with both low- and high-intensity development. Surprisingly, the fish IBI tended to increase with increasing agricultural land use, while the benthic IBI did not show a significant relationship with the amount of agricultural land in a catchment. Forest land use did not show a significant relationship to the fish IBI, although the high number of forested sites that are impacted by acidic deposition and AMD may confound this result. Forest land use was significantly correlated with the benthic IBI and removing sites that were impacted by acidic deposition and AMD made this relationship stronger. Wetlands, which occupy no more than 5% of a catchment area, were not significantly correlated to either the fish or benthic IBI. The Hilsenhoff Biotic Index showed similar relationships to all types of land use with the exception of agriculture. In this case, Hilsenhoff Biotic Index scores increased (indicating increased degradation) with an increased percentage of agricultural land. This result indicates that the Hilsenhoff Biotic Index may better detect the organic pollution associated with agricultural fertilizers, a compelling reason to use it as an ancillary indicator to the IBIs.

In order to determine how MBSS results for stream chemistry, physical habitat, and biological communities vary from year to year and with changes in weather conditions, year-to-year variability in several parameters was examined. Within the three basins resampled by the Survey in two different years (Youghiogheny, Patapsco, and Choptank), the mean value in each sample year for the fish IBI, benthic IBI, PHI, and nitrate-nitrogen concentration were examined. Although some small differences were detected, virtually all were within the range of error (±1 standard error). Statewide, Maryland received an average of 38% more rainfall than normal in 1996, while 1995 and 1997 each received an average of 7% less rainfall than normal. However, the large amount of rain that fell in 1996 did not result in predictably lower (or higher) values for any of the parameters examined.

This 1995-1997 MBSS report applies analyses using the fish and benthic IBIs to differentiate among the multiple contributing stressors of acidification, physical habitat degradation, nutrients, and land use on Maryland streams. Statewide, physical habitat degradation was the most extensive source of stress, affecting 52% of non-tidal stream miles. The relative ranking of the extent of other stressors was as follows: lack of riparian vegetation 28%, acidic deposition 21%, agricultural land use 17%, urban land use 12%, and acid mine drainage 3%. Overall, 72% of the sites sampled in the 1995-1997 MBSS were affected by at least one of these six stressors. The importance of these stressors varies considerably among basins and may combine in different ways to produce large cumulative effects on Maryland streams. A preliminary investigation was made into how the combined stressors affect the fish and benthic IBIs. Using multiple regression analysis, fish IBI scores decreased significantly with an increase in urban land use, nitrate-nitrogen concentration, and the presence of AMD. Fish IBI scores increased significantly with an increase in agricultural land use and with improved physical habitat quality. Neither the width of riparian vegetation (as measured within the 75-m segment) nor the presence of acidic deposition were significant factors for explaining variation in fish IBI scores statewide. Statewide, benthic IBI scores decreased significantly with an increase in urban land use and with the presence of AMD. Benthic IBI scores increased significantly with improved physical habitat quality and increased riparian buffer width. Surprisingly, benthic IBI scores also increased with the presence of acidic deposition. Neither the percentage of agricultural land nor the concentration of nitrate-nitrogen were significantly correlated with the benthic IBI in the multiple regression model. In order to examine site-specific stressors, a stressor matrix was created for the more than 500 sites with either a fish or benthic IBI score less than 3.0. The values obtained at each site for 32 parameters were arrayed in a matrix and compared to a threshold value for each parameter (e.g., urban land use > 25% or NO_3-N > 2 mg/l) to help identify potential stressors at each site.

Biodiversity is more than just the number of species or the IBI score of a stream, it is "the variety of life and its processes" at four scales (levels of organization): genetic, species, ecosystem, and landscape. At present, the Survey does not address genetic diversity, nor define the ecosystem or landscape types found in Maryland, but it does contain detailed information on the distribution and abundance of aquatic species (especially fish) and the communities in which they reside (as measured by species composition at stream sites). Information from the 1995-1997 MBSS on rare species, vulnerable fish populations, non-native fish species, fish hybrids, species diversity of several taxonomic groups, and general fish community types addresses aspects of both the ecological and evolutionary phenomena statewide.

Statewide species richness and distribution were examined for fish, benthic macroinvertebrates, reptiles and amphibians, mussels, and aquatic vegetation. For fish, the most species-rich sites were in the central part of the state, but were scattered over more than one-third of Maryland. Only three fish species (largemouth bass, bluegill, and pumpkinseed) were present in all 17 river basins. When the distribution of fish species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, 51 occurred in all three regions and less than 10 were unique to any one region. Only 14 benthic macroinvertebrate taxa were present in all 17 river basins. In no basin did the percentage of taxa unique to the basin exceed 10%. In general, the statewide pattern of total amphibian and reptile species richness declined from the western to eastern parts of the State. Only two amphibians (green frog and bullfrog) and one reptile (northern water snake)were present in all 17 basins. Only five basins contained more than two mussel species and the North Branch Potomac contained none. Only the Choptank basin contained more than ten aquatic plant species; three basins contained seven to ten species.

In the 1995-1997 MBSS, the presence of six rare fish (stripeback darter, glassy darter, mud sunfish, ironcolor shiner, logperch, and flier), one rare salamander (Jefferson salamander), and four rare mussels (alewife floater, northern lance, Atlantic spike, and squawfoot) listed by the state Natural Heritage program were recorded. Statewide, 16 of the basins contained at least one fish species with a population size of less than 500 individuals (i.e., potentially at risk of extirpation). For example, populations of redfin pickerel and creek chubsucker, two species common to Maryland's Coastal Plain, may be at risk in the Patapsco basin where what little Coastal Plain and wetland habitats occur in this basin appear to be suffering losses from anthropogenic activities. Hybridization sometimes occurs when species are brought together through range expansions or habitat homogenization (usually as a result of environmental degradation). In the Middle Potomac basin about 1% of the *Lepomis* collected were hybrids, while in the Bush basin about 0.1% of the cyprinids were hybrids. Where non-native species make up a large proportion of the number of species or individuals in a basin, the natural ecological or evolutionary processes of the fish communities have likely been substantially altered. The occurrence of non-native fish was greatest in the eastern part of the state, with all basins exceeding 50% of stream miles containing non-native fish species. In contrast, basins in Western Maryland contained the lowest percentage of stream miles with non-native fish species. Although non-native fishes made up a fairly small percentage of the total fish fauna, these non-native species were widespread geographically. The Asiatic clam, an introduced freshwater mussel species, was found in 13 of the 17 basins sampled, but at relatively few sites within each basin.

Recognizing that the Survey does not currently provide the classification of ecosystem and landscape types needed for a complete assessment of aquatic diversity, several kinds of results can be used to identify streams and stream networks that are noteworthy examples of naturally functioning community or ecosystem types. For the purposes of the 1995-1997 MBSS, "high-integrity" streams were defined as those having a fish or benthic IBI greater than 4.0. Statewide, 20% of stream miles were rated good by the fish IBI and 11% were rated good by the benthic IBI. Thirty-eight sites were rated good by both the fish IBI and benthic IBI. The 38 sites with highest biological integrity were distributed among 10 river basins with nine in the Youghiogheny and eight in the Lower Potomac basins. These sites likely represent some of the most natural stream ecosystem conditions in Maryland. High-integrity streams are even more likely to support natural ecosystem processes in the absence of non-native species. Stream sites with only native fish species are fairly evenly distributed across the State. However, only 56 of the 955 streams sampled in the 1995-1997 MBSS have only native fish species and high biological integrity (based on fish IBI scores). Twenty of these streams are clustered in the far western part of Maryland, while the others are scattered mostly in the central part of the State. High-integrity streams with natives only provide another potential focus for biodiversity conservation efforts. One such candidate "biodiversity hotspot" is the northwestern region of the North Branch Potomac basin in the mainstem Savage River. Five of the other basins also contained sites with high native species richness and no non-native species, but in each case the sites were disjunct and no areas of concentration were evident.

The goal of the MBSS is to provide environmental managers and policymakers with the information they need to make effective decisions. For this reason, the Survey was designed to best answer a set of 64 management questions. These questions represented the direction and range of natural resource management concerns in 1995. The results described in this 1995-1997 MBSS report provide scientifically defensible and management-relevant answers to the majority of these questions, in some cases the first such answers ever obtained. At the same time, certain management concerns have changed and programmatic needs have evolved. Some of the 64 questions are less important, while new questions need to be answered. This report summarizes the answers to original MBSS questions and to other questions of concern by the following topics: physical characteristics, water chemistry, biological resources, landscape characteristics, resource-stressor associations, and resource-landscape associations. It also describes the relevance of these answers to current natural resource management and policy initiatives. Specifically, the 1995-1997 MBSS provides Maryland DNR with its first comprehensive picture of Maryland's stream resources. Information on the abundance and geographic distribution of stream resources, especially aquatic biota, is valuable for many groups with mandates for or interests in protecting Maryland's streams. For example, the MBSS's statewide and basinwide estimates for each fish species can be used to supplement DNR Fisheries Service data and better target management efforts. The Survey provides statewide, statistically rigorous data on the abundance and distribution of fish that can be used to validate and supplement Natural Heritage Program information. Information on concentrations, or hotspots, of biodiversity components are already being used to support the Power Plant Research Program's (PPRP) Smart Siting initiative and the Maryland's Unified Watershed Assessment as part of the Federal Clean Water Action Plan.

Perhaps the most important information provided by the 1995-1997 MBSS is the answer to the question—What is the condition of the resource? By developing two reference-based biological indicators—the fish IBI and benthic IBI—the Survey provides unprecedented opportunities for identifying degradation anywhere in the state. Recently this information was used to help designate both Category 1 (priorities for restoration) and Category 3 (priorities for protection) watersheds within Maryland as part of the Unified Watershed Assessment. Ultimately, it may prove valuable for Maryland Department of the Environment's (MDE) water quality standards program and preparation of its 303d list of streams not meeting designated uses and to determine total maximum daily loads (TMDLs).

The Survey also provides a critical baseline for conducting future monitoring to address short-term and long-term trends. Already, the Survey determined that the extent of acid-sensitive streams in Maryland has declined slightly since the 1987 Maryland Synoptic Stream Chemistry Survey (MSSCS). This result has important implications for assessing the effectiveness of controls instituted as a result of the 1990 Amendments to the Clean Air Act. Future trends detection using the MBSS baseline monitoring data will likely prove invaluable for addressing continued population growth (supporting the Governor's Smart Growth initiative) and climate change.

By collecting all these parameters in conjunction with biological data at each stream site, the Survey has also been able to make accurate estimates of the relative contributions of different stressors and to begin to investigate the cumulative effects they have across the landscape. Ultimately, solutions to stream problems depend on effective controls on or remediations at the source of degradation. Information on potential stressors from the 1995-1997 MBSS will support a number of environmental protection efforts including DNR's Integrated Natural Resource Assessment, EPA's Mid-Atlantic Integrated Assessment, MDE's water quality program, and the Maryland Tributary Strategy Team's plans to reduce nutrients contributions to the Chesapeake Bay.

MBSS information can also help DNR select, design, and implement watershed restoration efforts. Recently, data from the 1995-1997 MBSS was incorporated into the Integrated Natural Resource Assessment to identify 11 watersheds that will be the focus of future restoration efforts by DNR's Watershed Restoration Division under the Clean Water Action Plan and other initiatives. In the future, MBSS data may help other targeting efforts, such as the Governor's commitment to restoring 600 miles of riparian vegetation in Maryland by the Year 2010.

Finally, this report closes with a discussion of the natural resource management questions that remain to be answered and the implications for future implementation of the Survey. DNR has begun planning for a second round of the Survey by developing a new set of management questions that reflect what has been learned in the first round of the Survey, as well as the evolution of management and policy concerns since 1995. To this end, the Monitoring and Non-Tidal Assessment Division has solicited comments from all parts of DNR on a draft set of management questions that will help shape future design and methods refinements. New management concerns likely to be incorporated into the next round of MBSS monitoring include comparing among sample rounds for trends detection; extending into smaller and larger streams, (while delineating more stream types); characterizing and assessing at finer geographic scales; better characterizing existing and new stressors; refining existing indicators and developing new ones; and improving identification of rare species and other biodiversity components.

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